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SONIC BOOM: CONTAINMENT OR CONFRONTATION

By ANTHONY J. ORTNER†

"I know of no way of judging the future but by the past."—Patrick Henry

THE SONIC BOOM is a remarkable phenomenon the likes of which have not been matched since the discovery of the atomic bomb. Its initially playful character has developed into genie proportions whose flexing muscles may chance to bruise the ears of the entire world. In fact, what was once mere chance has soared the sonic boom into the fields of battle where it has assumed proportions of international stature. Will peaceful containment or the hue and cry of warlike confrontation prevail?

I. BACKGROUND

A. History

It was in the early 1940's that aircraft probably first reached the speed of sound. These booms during World War II dive bombing missions were rare and considered quite dangerous. In 1947, the rocket powered Bell X-1 piloted by Charles E. Yeager, achieved supersonic speed.¹ With the development of jet aircraft during and after the Korean War, supersonic speeds became an operational reality.² The thrill of air shows came when announcers enthusiastically presented the *sonic boom*!

The boom was lowered at Will Rogers Field, Oklahoma in 1956 when an Air Force air show presented same.³ The ensuing \$500,000 damage at the airfield⁴ and hundreds of claims⁵ by local property owners sobered the boom enthusiasts.

B. Tests And Public Reaction

Interest and need demanded a better understanding of this remarkable phenomenon. Tests were conducted at St. Louis, from July 1961 through May 1962; at Oklahoma City from February through July 1964; at Chicago from February through March 1965, and at Edwards Air Force Base in late 1967. The Air Force, Stanford Research Institute, Boeing Aircraft Company, the Federal Aviation Administration and many other organizations conducted tests and studied the results. The damage, public re-

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¹ D. BILLYOU, *AIR LAW* at 63, (2d ed. 1964).

² Roth, *Sonic Boom: A New Legal Problem*, 44 A.B.A.J. 218 (1958).

³ 12 AM. JUR. PROOF OF FACTS, *Sonic Boom* at 598 (1962).

⁴ *Id.*

⁵ Hammon, *More on Sonic Booms: Litigation is Showing Their Propensities*, 47 A.B.A.J. 1097 (1961).

action and official positions resulting therefrom are manifold indeed. Backing can be readily found for arguments pro and con.

Damage and noise appear to be the primary sonic boom resultants which are responsible for increasing public reaction to the various tests and other booms caused by military aircraft. Public reaction to the three early tests is shown in Table I.

TABLE I
SONIC BOOM TEST REACTIONS⁶

<i>Test Area</i>	<i>Number of Supersonic Flights</i>	<i>Number of Damage Claims Filed</i>	<i>Number of Formal Complaints</i>
St. Louis (1961-62)	150	1624	5000
Oklahoma City (1964)	1253	4629	15116
Chicago (1965)	49	2964	7116

In spite of conducting the Oklahoma City tests with an aviation oriented population, twenty-five percent of all the people interviewed stated they could *never* learn to tolerate sonic booms.⁷ Although the Chicago test had far fewer booms, the proportionate reaction was far greater (22 times greater as to damages, 12 times greater as to complaints) and perhaps more indicative of the potential reaction of the United States population.

The human as a reaction mechanism is complex and highly variable. Persons exposed to sonic booms display a pronounced increase in heart rate. Startle response is not harmful to the average healthy citizen, but the deleterious effects on persons in ill health must be considered. Dr. John A. Parr states:

Why should noise upset our health? Well, it's all due to an inborn alarm system that we have. A sudden loud noise spells danger and we react. In fact we automatically get ready either to defend ourselves or for flight. Our muscles tense and we jerk, our abdominal blood vessels contract to drive extra blood to our muscles and this produces that feeling of the stomach turning over, and in an instant the liver releases stores of glucose to provide fuel for the muscles which may have to fight or run. This internal upheaval if repeated again and again is exhausting physically and mentally, and ultimately can cause a nervous breakdown, and then it is but a step to contracting one of the stress diseases.⁸

There are unlimited situations in which physical reactions can be triggered by a loud noise and prove injurious to persons or property. The surgeon in the midst of exacting surgical work, the construction worker bal-

⁶ C. Nixon & H. Hubbard, *Results of USAF-NASA-FAA Flight Program to Study Community Responses to Sonic Booms in the Greater St. Louis Area*, NASA TN-D-2705, May 1965; *Final Program Summary—Oklahoma City Sonic Boom Study*, FAA Report, SST-65-3, 17 Mar. 1965; D. Hilton, V. Huckel, & D. Maglieri, *Sonic Boom Measurements During Bomber Training Operations in the Chicago Area*, NASA TN-D-3655, Oct. 1966.

⁷ L. Beranek, *Noise*, SCIENTIFIC AM., Dec. 1966.

⁸ 112 CONG. REC. 8343 (1966) (Remarks by Representative Kupferman).

anced on a girder hundreds of feet in the air, the marksman taking meticulous aim in a championship match, or the demolitions expert carefully inserting the blasting cap to a charge of dynamite may all face a severe test of nerves when exposed to an unexpected sonic boom.

People react differently to the sonic boom depending upon frequency of occurrence, time of day or night, location (indoors or out), preoccupation of the moment and the particular signature (character) of the boom. Overpressures alone do not define boom exposure. Test data assembled into charts provide broad guidelines of public acceptance; however, once established they oftentimes tend to become the more rigid limits of the possible and impossible. A summary of public reaction versus overpressures (in pounds per square foot) by the National Opinion Research Center follows:

3.0 psf—widespread	1.5 psf—scattered
2.5 psf—significant	1.0 psf—no significance
2.0 psf—probable	0.5 psf—acceptable ⁹

It is important to note that the only *acceptable* level listed is 0.5 psf and by inference all higher levels are not acceptable.

II. TECHNICAL FACTORS

A. Boom Generators

Any object or particle traveling in the atmosphere at the speed of sound or greater causes the piling up of air molecules in compressed array. Such molecular disturbance dissipates at the speed of sound in the form of a discontinuity or shock wave otherwise known as the sonic boom. Supersonic aircraft and rockets are particularly noted for this effect. A person standing near a passing bullet will hear a sharp "crack" as the passing shot induces a mini-boom. In other words, a sonic boom is a 760 mile per hour mass of compressed energy which can cause destruction in its path equivalent to the force of an atomic explosion at ground zero.¹⁰ The faster an aircraft travels, the more air molecules are stacked up, and the greater the resulting overpressures. Fighter aircraft, as noted earlier, are capable of highly destructive sonic booms. As the size, weight, and speed of the aircraft increase there is a marked gain in the impact and extent of the sonic boom. An aircraft in supersonic flight carries along a bow shock and a tail shock that slide over the earth's surface in the direction of the vehicle. This effect is often referred to as unrolling the "boom carpet." On the ground these two shocks normally evolve into the N-wave shock pattern. First there is rapid initial pressure rise above atmospheric followed by a moderate rate of decrease to a point below normal atmospheric pressure equal and opposite the initial overpressure, then a rapid return to normal.¹¹ Thus the *total pressure variation* is actually double that of

⁹ 1963 FAA AD No. 442770 at 48.

¹⁰ 12 AM. JUR. PROOF OF FACTS, *Sonic Boom* 593 (1962).

¹¹ H. Ribner, *The Noise of Aircraft*, General Lecture 4th Congress of the International Council of Aeronautical Sciences, Paris, France, 24-28 Aug. 1964 in Institute for Aerospace Studies, University of Toronto, UTIAS Rev. No. 24, AFOSR 64-1310, (Aug. 1964) at 11. See Appendix I.

the popular overpressure data used by federal agencies. The bow shock and tail shock from small aircraft are heard as one noise by the ear whereas a large long aircraft such as the supersonic transport creates a double report readily discernible by the ear as two distinct booms, one caused by overpressure, the other by underpressure and both separated by a significant time interval of approximately 0.2 to 0.3 seconds.

Another critical value is the "cutoff Mach number" for the flight speed below which the shock wave will not reach the ground. Examples for flight at 36,000 feet give these respective cutoff values (where $M=1.0$ is the speed of sound):

$$M_c = 1.15 \text{ for level flight}$$

$$M_c = 1.57 \text{ for climb at an angle of } 21^\circ$$

$$M_c = 1.01 \text{ for a descent at an angle of } 21^\circ{}^{12}$$

A comparison of the numbers above indicate that a supersonic descent in aircraft will produce a greater boom effect towards the earth's surface than either of the other two flight altitudes. Curved flight paths and linear acceleration provide possibilities for focusing and defocusing the shocks.

The principal supersonic aircraft expected to be used commercially are the SST, the Concorde and the Russian TU-144. Comparisons follow:

TABLE II
SST COMPARISONS¹³

Aircraft	Passengers	Range	Speed	Fleet Size	
				Min	Max
SST	300	4000+Mi	1800 MPH	300	1200
Concorde	124	4000+Mi	1450 MPH	300*	
TU-144	126	4000+Mi	1550 MPH	100*	

* Estimate provided

B. Receptors

The earth, structures, animals, and humans are the principal receptors of the direct and indirect effects of the sonic boom. Particular portions of the earth may be jeopardized such as mines, areas subject to landslides¹⁴ or snowslides, geological formations¹⁵ of historic or tourist interest.

Structures are subject to sonic boom damage and can reflect, redirect, amplify or alterate pressure effects depending upon angular relationships with the approaching shock wave-front, the composition of materials, conformation, size, and presence of defects either patent or through deterioration. The 1964 test shows that damage normally occurs at stress points within a structure. Built in stresses due to drying out of green lumber, hydration of concrete, and poor quality of workmanship create a potential

¹² *Id.* at 12.

¹³ Mount, *Ban the Boom?* NAT'L REV., 8 Aug. 1967 at 850; *The Boom That's Brewing a Storm*, BUS. WEEK, 28 Oct. 1967 at 64.

¹⁴ *The Boom That's Brewing a Storm*, BUS. WEEK, 28 Oct. 1967 at 65.

¹⁵ *Id.* at 67. Formations in Bryce Canyon, Utah and the cliff dwellings at Mesa Verde, Colo. were reported damaged by sonic boom; 113 CONG. REC. H352 (daily ed. 18 Jan. 1967).

failure of building materials.¹⁶

An almost completed control tower at Dannelly Field, Montgomery, Alabama was destroyed by sonic boom 18 May 1958.¹⁷ Heavy metal girders were twisted out of shape and the aluminum spandrels were ripped off.

In the case of *Fireman's Ins. Co. v. Alexander*,¹⁸ a sonic boom destroyed a well constructed frame and metal warehouse. The court interpreted the insurance policy covered "loss by aircraft" when "[T]he force and pressure of such air disturbance, created by the aircraft, unseated the girders beneath the building and capsized it."¹⁹ The *Oklahoma Journal* on 1 June 1967 reports that a federal court jury awarded \$10,000 for loss when a single family house was split in two by sonic boom.²⁰ On 3 August 1967 the *New York Times* indicated that a sonic boom at Maunon, France caused the collapse of a farm house which killed three persons.²¹

Animals usually rely upon their keen sense of hearing as a warning device. This very fact plus the emotional skittishness of many species combine to produce unusual effects when they are exposed to a resounding boom. Ten thousand chickens subjected to the entire six month Oklahoma City test sustained some or all of these effects: disorientation neurosis, loss of feathers, stoppage of egg laying, internal bleeding and death.²² Only 4,000 of the original 10,000 chickens remained alive at the end of the period.²³

Humans are a remarkable specie for study under the effects of the boom. Some say they like it! Some tolerate it while others organize against it.²⁴ Further, some are so reactant to noise as to threaten violence²⁵ or even become insane.²⁶

Dr. Samuel Rosen, an ear surgeon and investigator of the hearing loss problem, describes a "some day" national chronic noise syndrome:

At an unexpected or unwanted noise, the pupils dilate, the skin pales, mucous membranes dry up, there are intestinal spasms, and the adrenals explode secretions. The biological organism, in a word, is disturbed.²⁷

¹⁶ 2 Final Report—Studies of Structural Response to Sonic Booms in Connection with the Supersonic Transport Research Program, FAA Contract No. FA-64-AC-6-526, 5 Feb. 1965 at IV-1.

¹⁷ *Supra* note 5 at 1099.

¹⁸ 328 S.W.2d 350 (Tex. Civ. App. 1959), Annot. 74 A.L.R.2d 750. It may well be that the natural frequency of the structure was in consonance with the push-pull rate (overpressure and underpressure) of the shock wave thus resulting in significant damage.

¹⁹ *Id.*

²⁰ *Jet Boom Claim Paid*, OKLA. J., 1 June 1967.

²¹ J. Hess, French Investigate Deaths of 3 Linked to Superjets' Boom, N.Y. Times, 3 Aug. 1967 at 24-L. The article further notes eight other deaths attributed to sonic booms; four from heart attacks, two from runaway horses and two from the collapse of a well.

²² 112 CONG. REC. H17440 (1966) (remarks by Representative Kupferman).

²³ *Id.*

²⁴ Dr. William A. Shurcliff directs the Citizens League Against the Sonic Boom in Cambridge, Mass.

²⁵ 112 CONG. REC. H17411 (1966) (remarks by Representative Kupferman). At Kennedy International Airport jet noise is so aggravating that residents have more than once blocked the runways in protest, and one woman threatened to blow up the control tower to free herself and her family from the plague of intolerable noise.

²⁶ *Id.* at H17438. A medical expert wrote: "It is not an exaggeration to say that quite a few cases of insanity are caused by nervous systems that cannot adjust to the constant bombardment of noise."

²⁷ 113 CONG. REC. H15731 (daily ed. 21 Nov. 1967).

The noise sense of the ear and the tactile sense of the entire body surface additively signals the brain of a sudden significant environmental change. The ensuing response is unpredictable but oftentimes is a quick unthinking reflex that can cause problems as mentioned earlier.

C. Significant Variables

Early tests developed a volume theory of accounting for and predicting the sonic boom overpressures. Based on the volume theory, boom effects dissipated more rapidly in the atmosphere than was originally forecast by rigorous scientific calculations. As a result, the overpressures actually achieved in the Oklahoma City test were lower than those strived for under stringent controls. Although 2.0 psf overpressure was sought, results averaged 1.6 psf with wide variations including several readings at 4.4 psf.²⁸ After an appropriate theory change was made, it was found that the effect of various atmospheric conditions was not only a function of Mach number, but could change the range plus or minus twenty-five percent in widely varying weather conditions.²⁹ Winds in combination with temperature variations can cause extreme lateral extension of the shock wave, focusing, or cutoff.³⁰ Any form of aircraft acceleration, lateral, longitudinal or normal, can cause extreme focusing of the sonic boom. Thus focusing causes *Superbooms*. Flight test measurements have established magnification factors of 2.5 for longitudinal acceleration and up to 4.0 for normal acceleration as might be caused by clear air turbulence.³¹ Acceleration during climbs, turns, and pushovers appear to be the major superboom maneuvers. While the boom carpet of level flight follows the aircraft path, the superboom areas are fixed cusp-shaped areas and do not move with the aircraft. They tend to be about one square mile in size resulting from the overlapping additive shock waves. Thus many factors are at work.

The SST, at weights of up to 250 tons, requires a like degree of lift to maintain cruise flight. The required lift is developed by increasing slightly the knife edge aspect of the half acre wing area. This increased wing aspect in fact serves as a battering ram at speeds of Mach 3.0 (1800 mph) which causes massive stacking of air molecules with such drastic violence as to extend this pressure shock against the earth's surface in measure far greater than lightweight, negligible lift supersonic fighters.

Thus the SST presents a new problem not common to ordinary supersonic aircraft. Where volumetric theory of accounting for degree of overpressures at the surface holds true in early tests, the B-58, B-70, and SST must rely upon the *additional* lift theory as well. The combined lift and volumetric effects of the SST induced sonic boom will not be known with any degree of certainty until detailed flight tests are conducted.

²⁸ 2 Final Report—Studies of Structural Response to Sonic Booms in Connection with the Supersonic Transport Research Program, FAA Contract No. FA-64-AC-6-526, 5 Feb. 1965 at IV-1.

²⁹ E. Kane, *Some Effects of the Non-Uniform Atmosphere on the Propagation of Sonic Booms*, Proceedings of the Sonic Boom Symposium, 70th Meeting of the Acoustical Soc. of Am., St. Louis, 3 Nov. 1965 at 26-27.

³⁰ *Id.* at 28-29.

³¹ D. Maglieri, *Some Effects of Airplane Operations and the Atmosphere on Sonic-Boom Signatures*, 70th Meeting of the Acoustical Soc. of Am., St. Louis, 3 Nov. 1965.

Based upon the foregoing variables and numbers of aircraft proposed for use by 1980 the probabilities and possibilities are astounding. The following hypothetical case may serve to show the possibility of that one in a thousand catastrophe. Given:

- (1) World SST fleet: 800 (only 200 airborne at one time)
- (2) SST airports worldwide: 40
- (3) Width of boom path: 50 miles
- (4) Cruise speed: Mach 3.0
- (5) Surface overpressure from SST cruising at 65,000 ft: 2.0 psf
- (6) Altitude: sixty to seventy-thousand feet
- (7) Maximum weather variable: plus or minus .25 Mach
- (8) Maximum acceleration multiples: 2.5 longitudinal, 4.0 normal, and 1.6 turns

Event I: Five SST's pass within twenty-five miles of each other somewhere over New York State as follows: the first accelerating, the second in turbulence, the third in a standard rate turn, the fourth a pushover, and the last in cruise flight. Since the cross-over effect of aircraft provide additive results this simple expression applies:

$$\begin{array}{ccccccc} \text{(Wx)} & \text{(SST's)} & \text{(Over-} & \text{Acceleration} & \text{(Push-} & & \\ & & \text{pres.)} & \text{(long.)} & \text{(normal)} & \text{(turn)} & \text{over)} \\ & & & & & & \text{(cruise)} \\ (1.25) & (5) & (2.0) & (2.5) & (4.0) & (1.75) & (1.12) & (1.0) & = (245 \text{ psf}) \end{array}$$

Event II: Using the first three aircraft at only fifty percent of the maximum multiples produces:

$$(1.12) \quad (3) \quad (2.0) \quad (1.75) \quad (2.5) \quad (1.37) \quad = (40 \text{ psf})$$

Should there be a one in a thousand chance of Event II occurring, the resulting catastrophe could make prohibitive any such operation in the future.

Event III: Using the second aircraft at only twenty percent of the maximum multiple produces:

$$(1.05) \quad (1) \quad (2.0) \quad (1.6) \quad = (3.36 \text{ psf})$$

The maximum 4.4 psf overpressure actually achieved during the Oklahoma City test when the arbitrary upper limit was established at 2.0 psf with strict controls applied, indicate the plausibility of values that can be seen in the events above. Very small deviation caused a two-thirds increase of overpressure in Event III. The drastic possibilities deserve very strict investigation.

III. LEGAL ASPECTS

The question of public acceptance of sonic booms is a legal matter. Social necessity has held sway over many associated inconveniences of progress. However, in the name of progress, rights of the individual may suffer until the rule of law determines an equity balanced to suit the changing times and mores of society.

A. *Strict Liability*

The sonic boom is a mischievous phenomenon, difficult to control should

it escape. The *Rylands v. Fletcher*³² rule first developed the ultrahazard theory and resulting strict liability rule. In *Boyd v. White*³³ the rule of 1954 deleted aircraft from being so dangerous as to be ultrahazardous. The Restatement of Torts³⁴ lists an activity as ultrahazardous if it involves a risk of serious harm which cannot be eliminated by the exercise of the utmost care and is not a matter of common usage. As shown earlier the sonic boom is dependent upon numerous variables which cannot be controlled by utmost care. Since the sonic boom is still regarded as an ultrahazardous activity,³⁵ strict liability applies to damages so incurred. Recognition is allowed that technological developments may so greatly improve supersonic flight that the ultrahazardous classification may change. Boeing's announced design changes of November 1967, were specifically made to reduce boom hazards.³⁶ Apparent growing criticism across the United States may well preclude any future change in the strict liability ruling for boom induced damage.

The courts do not as yet take judicial notice that a sonic boom is an explosion,³⁷ hence the fact must be proved. An explosion is sudden release of great pressure accompanied by noise. This is certainly true of the sonic boom and reinforces its ultrahazardous label. In *Schlansky v. Augustus V. Reigal, Inc.*,³⁸ negligence was established by showing damage occurred from concussion and the testimony of an expert, who had visited the scene, that excessive explosives had been used. A recent article³⁹ presented the analogy in the case of the sonic boom where it is shown "that the aircraft was going too fast considering the altitude at which it was flying or the maneuvers in which it engaged. This could be determined by the amount of overpressure produced." It was further noted that a blaster is absolutely liable for any damage he causes, with or without trespass. Sonic boom blasting needs like expert testimony for recovery.

B. Trespass, Nuisance And Taking

Trespass is based on a physical invasion of the airspace over one's property. In the case of *United States v. Causby*⁴⁰ the Supreme Court ended "ad coelum" ownership and went on to say that ownership to the sky "has no place in the modern world."⁴¹ Also, "the airspace, apart from the immediate reaches above the land is part of the public domain."⁴²

³² 3 H.&C. 774, L.R. 1 Ex. 265, L.R. 3 H.L. 330 (1868).

³³ 128 Cal. App. 2d 641, 276 P. 2d 92 (1st D.C.A. 1954).

³⁴ RESTATEMENT OF TORTS § 520 (1938).

³⁵ RESTATEMENT (SECOND) OF TORTS § 520A (Tent. Draft No. 11, 1965).

³⁶ *Design is Modified for Supersonic Jet*, N.Y. Times, 29 Nov. 1967 at 95, col. 3. The changes will "lessen the sonic boom." Plans include lengthening the plane 12 feet to 318 feet over-all and adding two "canards" like two small wings near the front for stability in slow flight. Elimination of the upper deck cargo compartment will decrease volume. This together with the longer, more streamlined nose will reduce the boom to equal that produced by the Concorde. The apparent cargo weight saving will reduce the lift induced boom.

³⁷ *Alexander v. Fireman's Ins. Co.*, 317 S.W.2d 752 (Tex. Civ. App. 1958).

³⁸ 9 N.Y.2d 493, 174 N.E.2d 730 (1961).

³⁹ Note, *Sonic Booms—Ground Damage—Theories of Recovery*, 32 J. AIR L. & COM. 596, 604 (1966).

⁴⁰ 328 U.S. 256 (1946).

⁴¹ 328 U.S. at 261.

⁴² *Id.* at 266.

The Federal Aviation Act relates:

There is hereby recognized and declared to exist in behalf of every citizen of the United States a public right of freedom of transit through the navigable airspace of the United States.⁴³

"Navigable airspace" means airspace above the minimum altitudes of flight prescribed by regulations issued under this chapter, and shall include airspace needed to insure safety in takeoff and landing of aircraft.⁴⁴

Restatement of Torts (Tentative Draft No. 9) states:

Flight by aircraft in the airspace above the land of another is a trespass, if but only if, (a) it enters into the immediate reaches of the airspace next to the land, and (b) it interferes unreasonably with the other's use and enjoyment of the land.

Trespass is no longer used directly in aviation noise litigation except in the instance of taking. Taking, as first developed in *Causby* and later in the case of *Griggs v. Allegheny County*,⁴⁵ is flying so low and so frequent as to be a direct and immediate interference with the use and enjoyment of the land.⁴⁶ In *Batten v. United States*⁴⁷ the court held there was no taking in the absence of overflights even though the consequences of such acts may impair the use of the property. The rule in *Loma Portal Civic Club v. American Airlines Inc.*,⁴⁸ held lateral noise impact enough for a taking without an overflight.

An amazing bit of juggling took place in the case of *Thornburg v. Port of Portland*.⁴⁹ The court ruled that before the plaintiff may recover for a taking of his property he must show activities unreasonably interfering with his use of his property, and in so substantial a way as to deprive him of the practical enjoyment of his land.

Further the court held that overflights are not a prerequisite of a taking and a noise nuisance can amount to a taking. "By inquiring whether the alleged noise nuisance constituted a taking and by using a nuisance approach in ruling on admissibility of evidence the court gave emphasis to public interest."⁵⁰ Taking and nuisance were amplified as follows:

A nuisance, although a tort, does not contemplate a physical invasion of the property of another, but the use of a person's own property in such a way as to interfere with another's free enjoyment of his property.⁵¹

It is the right of an owner of land to use his land in any lawful manner, and it is only when the manner of use creates a grave interference with another's enjoyment of his property that the law will seek to redress this type of wrong. This is a natural requirement of organized society. There must be some give and take to promote the well-being of all. The underlying basis in nuisance law is the common-sense thought that in organized society there

⁴³ 72 Stat. 740, 49 U.S.C. § 1304 (1964).

⁴⁴ 72 Stat. 737, 49 U.S.C. § 1301 (24) (1964).

⁴⁵ 369 U.S. 84 (1962).

⁴⁶ *United States v. Causby*, 328 U.S. 256 (1946).

⁴⁷ 306 F.2d 580, 8 Av. Cas. 17,101 (10th Cir. 1962).

⁴⁸ 39 Cal. 2d 708, 394 P.2d 548, 9 Av. Cas. 17,156 (1964).

⁴⁹ 223 Ore. 178, 376 P.2d 100, 8 Av. Cas. 17,281 (1962).

⁵⁰ L. Tondel, *Noise Litigation at Public Airports*, Paper Presented to the Jet Aircraft Noise Panel, Mar. 1966.

⁵¹ 223 Ore. 178, 376 P.2d 100, 114 (1962).

must be an adjustment between reasonable use and personal discomfort.

No such consideration is involved in the law of trespass. . . . It is the taking of an owner's possessory interest in land as compared with interfering with an owner's use and enjoyment of his land that distinguishes a trespass which is a "taking" from a nuisance, which is not.⁵²

Thus in *Thornburg* a taking could be partial rather than complete as in the sense of eminent domain. Also, the plaintiff may keep his property and still collect damages. In the second *Thornburg* case:

If the jury finds an interference with the plaintiff's use and enjoyment of his land, substantial enough to result in *loss of market value*, there is a taking.⁵³

According to the *Thornburg* rulings, where "inverse condemnation" is claimed for partial loss of property value, balancing of interests by tort law is not involved. The Washington Supreme Court stated that inverse condemnation cases are the same as direct condemnation cases where damage is assessed, regardless of degree of interference or damage.⁵⁴

However, in *Bennett v. United States*,⁵⁵ the plaintiff alleged taking of an air easement by sonic boom. The Oklahoma District Court held that the physical invasion of sonic shock waves of jet aircraft operated by the United States did not constitute a physical taking as opposed to a mere use and trespass. The boom source was six to nine miles high and not low and directly above land so as to constitute a taking. Through wide use of stipulation the sonic boom was acknowledged as well as frequency and overpressures.

There are overlapping areas in the trespass, nuisance, and taking theories and much disagreement between states. Very close scrutiny may provide a future opening in this area against nondamage effects of the sonic boom. The *Thornburg* rules appear to give significant possibility for recovery.

C. Damage And Proof Of Cause

The sonic boom has induced widespread glass and plaster damage and some structural damage. The telltale signs are the shards of glass that disperse in the direction of the retreating aircraft sometimes falling seventy-five to one hundred feet from the point of origin and the large X crack in the plaster from corner to corner of the surface.⁵⁶ Structural members fail from overload at normal stress points and at flaws.

In *Dabney v. United States*⁵⁷ the plaintiff did not prove damage by sonic boom. The court held that the overpressures were not great enough to cause damage. The basis for this reasoning was the testimony of government experts who conducted and analyzed the Oklahoma City test. Their new test buildings sustained no damage.

An interesting note about boom glass damage was found in *Neber v.*

⁵² *Id.* at 114-15.

⁵³ *Thornburg v. Port of Portland*, 415 P.2d 750 (Ore. 1966).

⁵⁴ L. Tondel, *supra* note 50.

⁵⁵ 266 F. Supp. 627 (D. Okla. 1965).

⁵⁶ 12 AM. JUR. PROOF OF FACTS §§ 3-5, at 595-99.

⁵⁷ 249 F. Supp. 599 (W.D.N.C. 1965).

United States.⁵⁸ Evidence established that sonic boom caused plaster and glass damage in the amount of \$750.00.

The window did not break because of the excessive pressure per se "but because the window which was opened at the time was slammed by the boom, and the slamming broke the window."⁵⁹

Judge Larsen noted:

This type of cause is not the same as proximate cause, which is the efficient cause, or the one which necessarily sets in operation the factors which accomplish the damage.⁶⁰

The fact of general sonic boom damage is well known but the specific case proof to date has been difficult. As in *Coxsey v. Halloby*⁶¹ stipulation has been used generously in boom cases. Here parties agreed among other items that:

Faster than sound aircraft generate sonic booms which give off a loud noise (like a thunder clap) and cause some vibration. Both the noise and vibration last a fraction of a second. Varying metrological and climatic conditions which vary from season to season affect the sonic boom. Overpressures recorded 1.5 psf to 2.0 psf.

Another variation arose in the case of *Lorick v. United States*.⁶² The court noted that although the plaintiffs introduced no direct evidence or testimony to the effect that the overflights had any causal connection with the damages alleged; nevertheless, their testimony that none of the damages existed prior to the overflights and that such damages were found immediately thereafter could support an inference of causal relationship between the overflight and the alleged cause. The defendant testified that the flight was subsonic thus answering the inference adequately.

Proof of causation appears to be the prime difficulty in a suit for damages. In the cases above with a lone possible defendant (the United States), establishing the complete causative chain in fact and not probability or conjecture can be very difficult even though identity is apparent. Witnesses to the sound and vibration are easily obtained as well as expert witnesses to give testimony that some aircraft can fly supersonic.⁶³ In order to bring some cases to court without undue expense, many difficult areas are presented via stipulation as in *Coxsey v. Halloby* above. Once it has been established that a boom occurred then the boom must be related to the damage. Even though this was well done in *Neber v. United States*, the United States Air Force investigation teams in the Oklahoma City area recorded denial of 3,869 out of 4,629 claims filed. Government investigators seldom spent over twenty minutes in examination while insurance representatives spent an hour or more. Rigid interpretation of Air Force policy was the rea-

⁵⁸ 265 F. Supp. 210 (D. Minn. 1967), noted in 34 J. AIR L. & COM. 139 (1968).

⁵⁹ *Id.*

⁶⁰ *Id.*

⁶¹ 231 F. Supp. 978 (D. Okla. 1964).

⁶² 267 F. Supp. 96 (D.S.C. 1967).

⁶³ 12 AM. JUR. PROOF OF FACTS § 6, at 599 (1962).

son for the large number of claims denied.⁶⁴ An example of this is shown in *Neher* where damage in an adjacent room was ruled out because the old and new plaster cracks could not be sorted out. Thus in instances of old dusty plaster cracks which finally give way no recourse is allowed. It is interesting to note that Air Force policy in late 1966⁶⁵ acknowledges damage to defective materials can occur at overpressures as low as 1.0 to 2.0 psf.

Causation is an elemental consideration. Generally it is indefinable,⁶⁶ like the color yellow, but we have a grasp of it and correctly apply it to real events in a real world. The judge or jury must process the evidence offered on the cause issue. The correct application of cause in its simplest form occurs when one sees (or likewise senses) the event. In the absence of witnesses or other facts, we depend upon scientific theory. The causal relation might be known but its exact mechanism may not be known. Direct observation, inferences about observable sequences, and *inferences about unobservable sequences*, can each have a high degree of certainty. It is in the area of inference about the unobservable sequences that expert and scientific testimony will complete most of the sonic boom probabilities, possibilities and facts. Since there is no sole cause of anything, it is not necessary to find all causes, but only some of them. Evidence based upon circumstances must be such that the result alleged is a probability rather than a possibility;⁶⁷ however, it need not exclude every other reasonable conclusion,⁶⁸ and the plaintiff has a choice of the most reasonable inference.⁶⁹ Since the burden of proof is a legal requirement⁷⁰ a preponderance of proof is necessary in the weighing of factual probabilities for a finding in favor of the plaintiff.⁷¹ However, it is not necessary to tie all the loose ends together.

Whenever it can be said with fair certainty that the rule of conduct relied upon by the plaintiff was designed to protect against the very type of risk to which the plaintiff was exposed, the courts have shown very little patience with the efforts of defendant to question the suffering of the proof on cause.⁷²

D. Unknown Defendant

With numerous supersonic jets from the military, the airlines, foreign countries, and private industry (executive models are already on the drawing boards) creating sonic booms all across the country, identification of the damaging party is a practical impossibility. With the SST at 60,000 feet, it will be over *twenty* miles away when the boom is heard. Split second timing and accounting for all the various agencies that might have had

⁶⁴ Air Force Logistics Command Pamphlet, AFLCP 85-1, 13 Dec. 1966.

⁶⁵ *Id.*

⁶⁶ A. Brecht & F. Miller, *The Test of Factual Causation in Negligence and Strict Liability Cases*, WASH. U. STUDIES, St. Louis, Mo. (1961).

⁶⁷ *Doane v. Farmers Co-op Co.*, 250 Iowa 390, 94 N.W.2d 115 (1959), Annot. 81 A.L.R.2d 128 (1959).

⁶⁸ *Prior Lake State Bank v. National Surety Corp.*, 248 Minn. 383, 80 N.W.2d 612 (1957), Annot. 57 A.L.R.2d 1306 (1957).

⁶⁹ *Miller v. Watkins*, 355 S.W.2d 1 (Mo. 1960), Annot. 90 A.L.R.2d 1426 (1960).

⁷⁰ O. FISK, *FUNDAMENTALS OF THE LAW OF PROOF IN JUDICIAL PROCEEDINGS* 53 (1928).

⁷¹ A. Brecht & F. Miller, *supra* note 66 at 85.

⁷² Malone, *Ruminations on Cause in Fact*, 9 STAN. L. REV. 60, 73 (1956).

an aircraft in supersonic flight traversing the earth at one-half miles per second would not be feasible. Even by breaking any "conspiracy of silence"⁷³ among supersonic aircraft users to obtain all schedules, routing and other data, the plaintiff still has a losing circumstantial case. As with a "hit and run" driver the circumstances must be proved, and must all point in the same direction, and together must be irreconcilable with any other reasonable hypothesis than that of guilt.⁷⁴

Establishment of overpressure devices across the country would be costly. Since the "superboom" cusp covers approximately one square mile, it would require a pressure instrument in at least each square mile of even sparsely inhabited regions. This still would not detect all narrow, line type "superbooms" or other peculiar variations of overpressure.

The hue and cry of the population will require a solution to the proof of cause problem even if it does not become great enough to prohibit supersonic flights. A source of information used for the general benefit of the entire population is in order. A print-out of computer fed information from mandatory schedules, FAA radar flight following, transponder data, and most important, "black box" inflight data. These last data include all *accelerations* which the supersonic vehicle undergoes—longitudinal, normal, turn and pushover. Since these are the most critical with reference to the "superboom," this element is mandatory for a successful monitor program. As each flight occurs over a particular route, the airlines and the federal government can have an immediate estimate of the damage incurred. As stated earlier, the key is the data supplied by accelerometers in the "black box."

IV. RECOURSE

A. Injunction

An attempt at injunction against supersonic boom inducing flights in the case of *Coxey v. Halloby*⁷⁵ proved fruitless. Although the court had no jurisdiction, it held that the Oklahoma City test was authorized by federal law and as such fell within the discretionary function of the FAA. The use of injunction will no doubt be of little value for sonic boom litigants.

B. Administrative

The Military Claims Act⁷⁶ provides summary recourse. The vast majority of sonic boom claims have been settled under this act. Air Force policy requires that the claimants show a preponderance of evidence that the claimed damage was caused by the test.⁷⁷ This area of recourse, difficult at best, has satisfied many claims against military aircraft. One-eighth of the persons who believed they sustained damage reported it.⁷⁸ Perhaps the reasons were: Ignorance of reporting procedures, the feeling that the effort

⁷³ *Ybarra v. Spangard*, 25 Cal. 2d 486, 154 P.2d 687 (1944).

⁷⁴ 7 AM. JUR. 2d § 336 (1963).

⁷⁵ *Coxsey v. Halloby*, 231 F. Supp. 978 (D. Okla. 1964).

⁷⁶ 10 U.S.C. § 2733 (1964).

⁷⁷ *Supra* note 64.

⁷⁸ P. Borsky, *Community Reaction to Sonic Booms in the Oklahoma City Area*, National Opinion Research Center, Report No. AMRL-TR-65-37, Feb. 1965.

required to file a claim was greater than the benefit to be gained, and the discouragement transmitted by others about the mountains of "red tape." A resident of Madison, Ill., had a \$5.98 vase damaged by the boom. The ensuing red tape included:

First: A three page letter of explanation showing that the sonic boom could not have cracked the vase.

Second: A form entitled "Instructions for Submission of Claims."

Third: "Certificate of Ownership."

Fourth: "Claim for Sonic Boom Damage."

Fifth: "Statement of Claimant for Damages or Injury."

Sixth: "Statement of Witnesses."

Seventh: "Statement Concerning Insurance."⁷⁹

In all he received 18 pages of forms to be filled out—all because he did what the Air Force asked him to do by way of the newspaper. Who would go to all that trouble to replace a small pane of glass? Yet the damage is done on a widespread basis perhaps only developing a "slow burn" in the populace.

C. Action Against The United States

The Federal Tort Claims Act provides recourse against the United States in negligence cases only. Here again the discretionary function empowering high officials such as the President to plan and enunciate policy is an exception into which the development and test of the SST falls. In *Coxey v. Halloby*,⁸⁰ the court lacked jurisdiction because of the discretionary function exception.

The case of *Huslander v. United States*⁸¹ shows the importance of proving negligence in addition to damage. Here the pilot was acting under orders in the interest of national security. Only in those instances where it could be shown that the pilot violated regulations could negligence be claimed. Recognizing a problem the court digressed, "This decision points up the necessity for alternative means of honoring valid claims against the Government."

D. Legislation

Resolution of the sonic boom problem by legislation can occur in many ways. Simple banning of the boom comes to mind immediately. In the face of present national commitment that course is unlikely.

Perhaps legislation should force the federal government to assume all liability for boom damage since it regulates and controls the flow of air transport. In the case of *Ackerman v. Port of Seattle*⁸² the court held that with the Federal Aviation Act⁸³ of 1958, the Government had pre-empted the regulation of air traffic and in so doing assumed responsibility and liability for damage by overflight. This is a good area for legislation which in effect would simplify and consolidate claims procedures, relieve some

⁷⁹ Hon. J. Erlenborn, Extension of Remark, 113 CONG. REC. A4785 (daily ed. 26 Sept. 1967).

⁸⁰ 231 F. Supp. 978 (D. Okla. 1964).

⁸¹ 234 F. Supp. 1004 (W.D.N.Y. 1964).

⁸² 55 Wash. 2d 400, 348 P.2d 664 (1960), Annot. 77 A.L.R.2d 1344 (1961).

⁸³ 72 Stat. 731, 49 U.S.C. 1301 (1964).

of the identification problem and greatly reduce great quantities of litigation expenses thus paying for itself indirectly.

V. CONCLUSIONS

(1) The sonic boom is in the early process of being confronted by a public yet in the "slow burn" stage.

(2) More definitive study is needed on the sonic boom conducted on an international basis since most flights will cross national borders. This may achieve early agreement on common standards.

(3) If supersonic flight for the public is here to stay, legislation is needed to identify government as the responsible control agency responsible for damages and empowered to settle claims.

(4) Develop a positive computerized information center utilizing a "black box" concept as a key source. This will assist claimants and help the Government to run a safe and sane SST program.

(5) Develop the rule of law which can keep abreast of the ever quickening pace of technological progress.

APPENDIX I

